**PhD in Materials, Mechatronics and Systems Engineering**  
Research topics – Cycle 34  
Secondo bando / Second Call 2018

**DIPARTIMENTI DI ECCELLENZA / Departments of Excellence**

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Topic: **Variable impedance actuators based on composite elastomers for advanced robotics**

**P.I.: Marco Fontana, Luca Zaccarian, Devid Maniglio (UniTN), G.K. Lau (NTU)**

**Foreign partner institution:** Nanyang Technological University-NTU (Singapore)

**Synthetic description of the activity and expected research outcome**

Recent researches in Robotics aim at the development of a new class of systems that features intrinsic compliant mechanical response to guarantee safety and reliability in their interaction with environment and with human operators. In this context, new solutions are sought for actuation systems featuring adaptable mechanical impedance in order to guarantee variable/programmable response. The objective of this project is to study innovative variable impedance actuators (VIA) for advanced robotic systems that are able to effectively adjust/adapt their response to uneven/unpredictable loading conditions.

The candidate will be studying new architectures/designs of actuators and force/torque transmission systems that are based on pneumatic/hydraulic networks combined with advanced composite and smart material systems. Target applications includes robotic exoskeletons, humanoid robots and other advanced robots that are specifically conceived for interacting with humans and/or with unstructured environments.

**Keywords:** Variable Impedance Actuators (VIA); Pneumatic Networks, Composite Elastomer; Variable Stiffness.

More info: Asst. Prof. Marco Fontana email: marco.fontana-2@unitn.it

**Transversality of the project**

Areas of research that are involved in this PhD project:
- mechanical engineering;
- bioengineering;
- mechatronics and control;
- materials engineering.

**Ideal candidate** (skills and competencies):

You have a recently completed master degree in Mechanical, Mechatronics, Aerospace Engineering or other related fields. You have excellent academic qualifications and a passion for design of electro-mechanical systems and hardware development. Strong experimental and modelling skills are essential for this project.
- CAD design and mechanical design;
- modelling of mechanical systems (including finite Elements Modelling);
- basics of System Dynamics and Controls;
- special interests for and competence in electro-mechanical engineering design and prototyping.
### Topic B

**Topic:** **One step bioprinting of complex hierarchical biological tissues: intervertebral disc**

**P.I.: Antonella Motta, Sandra Dire' (UniTN), Rui L. Reis (University of Minho)**

**Foreign partner institution:** University of Minho (Portugal)

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**Synthetic description of the activity and expected research outcome**

- The research focuses on the optimization of bioprinting methods for the fabrication of biomedical prostheses by using cells loaded hydrogels, and in particular for the fabrication in a single step of an intervertebral disc scaffold/substitute constructs. Constructs should recapitulate the main properties/architecture/etc. of a healthy intervertebral disc while inducing a specific cellular activity and tissue regeneration in situ.

- Polymeric hydrogels based bioinks should be investigated and functionalized with biological moieties to better trigger and drive cellular metabolism and activity considering the above define aim. Moreover, studies will regard the bioink optimization in terms of processability, mechanical properties, rheological properties, degradation kinetics, and so on.

- The research activity will be developed for two years at the Department of Industrial Engineering of the University of Trento and for one year at the 3Bs group, University of Minho, Portugal.

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**Transversality of the project**

The project requires collaboration in different areas of the Department with main focus on biomaterials, chemistry, polymers science and engineering, regenerative medicine&tissue engineering.

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**Ideal candidate (skills and competencies):**

Master degree in scientific topics, in particular in materials engineering, biomedical engineering, biotechnology, chemistry and pharmaceutical technologies, and similar. English written and spoken: excellent.

Master thesis work focused on biomedical technologies, experience in materials physico-chemical characterization.
**Topic C**

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<tr>
<th>Topic: Measurement of physio-mechanical parameters for regenerative vertebral prosthesis and human posture optimization</th>
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<tr>
<td>P.I.: Mariolino De Cecco, Antonella Motta (UniTN), Keiichi Yasumoto or Hirokazu Kato (NAIST, Japan)</td>
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<tr>
<td>Foreign partner institution: Nara Institute of Science and Technology-NAIST (Japan)</td>
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**Synthetic description of the activity and expected research outcome**
This PhD program aims to develop an enabling technology for the “spinal care” in a holistic way: i) Vertebra and intervertebral disc regenerative prosthesis development will be considered together with ii) human posture optimization to maximise spinal health. Main goals will start from the design of an in vitro testing simulator to the development of Augmented Reality strategies based on real-time posture measurement.

Research objectives:

1. Measurement of physical parameters in mechanical stimulation enabled bioreactor culture condition and orthoses related parameters;
2a. Measurement of human body posture fed back in Augmented Reality to provide a feedback to the user that bear a vertebral implant to optimize his/her posture also taking into account parameters coming from sensors in the implant zone and orthoses stress;
2b. Development of adaptive furniture to optimize the human posture according to measurements of body posture, in vivo biological parameters and orthoses stress.

Note: 2a and 2b are in alternative and thus left to the will of the student (two different international co-tutors have proposed their will to contribute to the PhD project).

**Transversality of the project**
The project foresees competences of measurement (mechatronics area) and bioengineering (and materials area).
The colleagues involved are: Claudio Migliaresi, Antonella Motta, Devid Maniglio, Giandomenico Nollo, Paolo Bosetti, Alberto Fornaser.

**Ideal candidate** (skills and competencies):
- Master’s degree in mechatronics, mechanics, electronics or materials engineering or equivalent, with final mark higher than 105/110 or equivalent;
- Knowledge in the use of measuring instruments and signal processing;
- Good knowledge of the English language;
- Experience in the fundamentals of augmented reality, modelling and animation in Mixed Reality, bioengineering.
**Topic D**

**Topic:** High-Performance Photodetectors based on Engineered 2D Transition Metal Dichalcogenides Layers

<table>
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<tr>
<th>P.I.: Lucio Pancheri, Sandra Dirè, Marco Vittorio Nardi (UniTN), Emil List-Kratochvil (Humboldt-Universität zu Berlin, Germany)</th>
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<tr>
<td>Foreign partner institution: Humboldt-Universität zu Berlin (Germany)</td>
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**Synthetic description of the activity and expected research outcome**

The aim of this research activity is the development of novel optical detectors based on transition metal dichalcogenide materials, with particular focus on MoS2. Detectors based on this class of ultra-thin materials, consisting of a few atomic layers, can efficiently absorb electromagnetic radiation in a wide spectral range from ultraviolet to near infrared, converting it into an electrical signal. The active materials will be grown using industrially scalable technologies and their optical and electrical properties will be optimized using proper functionalization methodologies. The morphological and electronic properties of the materials will be analyzed using the instrumentation available at the host institutions. The detectors will be processed using well-established deposition techniques and will be characterized with respect to their electro-optical properties. Flexible substrates and electrode materials will be chosen with the goal of obtaining a high degree of conformability in the final devices. The main novelty of the proposed activity lies in the realization of detectors combining wide spectrum, high sensitivity and flexibility, that are enabled by the ultra-thin sensing layer and the versatility in the choice of the materials. The devices realized in this activity can find applications in the sensing of biological parameters (pH, indicators of oxidative stress) and pressure, exploiting their conformability to realize a minimally invasive readout system for optical sensors based on light absorption, scattering and fluorescence. The sensors could also be embedded in prototypes for the validation of regenerative prostheses and used for pressure sensing in soft robotics.

**Transversality of the project**

The research activity involves at least two areas of DII and at the Humboldt-Universität zu Berlin. In particular, at DII the chemistry and characterization labs will be used for the synthesis and characterization of the materials (S. Dirè) and the electronics lab for the design and characterization of the devices (L. Pancheri).

**Ideal candidate** (skills and competencies):

- Master in materials science, materials engineering, physics, chemistry and related degrees.
- Master thesis on an experimental activity related to development/characterization of materials and/or devices for applications in electronics/sensing
- English proficiency: B2, possibly C1
### Topic E

**Topic:** Maintenance policy optimization in the Industry 4.0 paradigm

**P.I.:** Matteo Brunelli, Dario Petri, Paolo Bosetti (UniTN), Mikael Collan (Lappeenranta University of Technology, Finland)

**Foreign partner institution:** Lappeenranta University of Technology (Finland)

### Synthetic description of the activity and expected research outcome

The research will consist of some phases/objectives:

- a preliminary and comparative study of optimization problems for the maintenance of industrial plans and technologies. In particular, “grouping” and “opportunistic” policies will be examined;
- development of new models for “predictive” maintenance according to the principles of Industry 4.0. Particular attention will be given to the process of information acquisition from sensors and techniques of numerical aggregation, also based on artificial intelligence;
- validation of the approach with a real-world case

### Transversality of the project

The project will be rooted in the Industry 4.0 paradigm and given the importance of maintenance activities for any industrial system, it will necessarily involve/interest other members of the department. Transversality emerges from the competences required to achieve the objectives of the project: operation research, automation and industrial systems, measures and informatics.

### Ideal candidate (skills and competencies):

- Familiarity with operations research and mathematical optimization
- Competences in industrial plants, production engineering and sensors
- Fluency in English
- Master degree in engineering
- Knowledge in programming language (Python, C++, …) and calculus (Matlab, R, Mathematica, …)
- Prior knowledge of modelling techniques used for preventive maintenance
**Synthetic description of the activity and expected research outcome**

The aim of the research activity is to realize biocompatible flexible optical sensors based on an architecture of optical waveguides (OWG). OWGs are connected through optical fibers to an input system of LEDs and an output read out array detecting the changes of the light signals induced by the interaction with the physical or chemical quantities to be detected.

Such kind of architecture is suitable for several applications, ranging from robotics to medical diagnostic. For instance, pressure fields on the waveguides can induce signal losses which can be detected and whose amplitude can be used as a measurement of the external pressure.

In the present project, the structure will be exploited mainly as a flexible biosensor for specific biomarkers appearing during inflammation, cellular disease or cancer. For the detection the OWGs surface will be functionalized with specific biomolecules suitable for grafting the desired biomarker.

The grafting can be detected through the change of the surface refractive index, the development of optical absorption features at specific wavelength or the luminescence quenching of fluorescent dyes at the OWG surface.

The main novelty of this activity is the synthesis and the use of new fibroin based materials. Fibroin is a biocompatible natural material for which recently a new crosslinking procedure has been developed, by the group involved in the research project, allowing the production of fibroin photoresist films. Starting from this material, new procedures for the tuning of the refractive index and for the surface functionalization can be developed in order to making the material suitable for application in the field of optical flexible sensors.

Moreover, in order to develop a multipurpose system, polysiloxane based systems will be realized in order to test the sensitivity and the feasibility of the transmission and detection set-up. Such systems could be the basis for flexible tactile sensors and may be used as support for new materials devoted to biosensing.

**Transversality of the project**

The research activity involves at least three areas of DII and at the School of Engineering of the Virginia Commonwealth University. In particular, at DII the characterization lab for the optical analyses (Alberto Quaranta), the Biotech Lab (Antonella Motta and Devid Maniglio) for the synthesis of the materials and the Electronic Lab (Lucio Pancheri) for the development of the integrated structure.

**Ideal candidate (skills and competencies):**
- Master in Industrial Engineering (either chemistry or materials engineering), Physics or Chemistry.
- Very good knowledge of english: B2/C1. Experience and skills in the experimental production and characterization of advanced materials will be positively evaluated.
**Topic G**

**Topic:** Polymer-derived ceramics cellular structures from replica of 3D printed lattices for bone tissue applications

**P.I.:** Gian Domenico Sorarù, Antonella Motta (UniTN), Joshua Pearce (Michigan Technical University - MTU)

**Foreign partner institution:** Michigan Technical University - MTU (USA)

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<tr>
<th>Synthetic description of the activity and expected research outcome</th>
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<tr>
<td>- Development and printing nano/meso-porous polyurethane cellular structures (work to be done at MTU, Prof. J. Pearce)</td>
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<tr>
<td>- Processing of polymer derived cellular structures from replica of 3D printed lattices. Study of the infiltration process, pyrolysis conversion and characterization of the physico/chemical properties of the ceramic components (work to be done at DII Glass and Ceramics Lab, Prof. G. D. Sorarù).</td>
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<tr>
<td>- Biocompatibility and bioactivity evaluation of the 3D printed ceramic structures (work to be done at DII, Biotech, Prof. A. Motta)</td>
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**Transversality of the project**
The research project will be at the frontier of Materials Engineering, Additive Manufacturing and Tissue Engineering.

**Ideal candidate (skills and competencies):**
- MS in Materials Science/Engineering, MS in Chemical Engineering or equivalent degrees
- A Master thesis in Materials Science/Engineering with focus on polymer/ceramic materials
- Fluent in English
- Research experience or scientific papers in the fields of Materials engineering with focus on polymer/ceramic materials
**Topic H**

**Topic:** Production of bioceramic components by P-3DP (Powder-based 3D Printing) starting from powders synthesized from natural products

<table>
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<tr>
<th>P.I.: Vincenzo M. Sglavo, Antonella Motta, Paolo Bosetti (UniTN), Pranesh Aswath (University of Texas at Arlington, USA)</th>
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**Foreign partner institution:** University of Texas at Arlington (USA)

**Synthetic description of the activity and expected research outcome**
- Synthesis of bioactive/osteogenic powders from natural products (silicates and carbonates contained in marine organisms, shells, diatomeas etc.)
- Production of granules by mixing with bioglass or other additives useful for successive consolidation or biocompatibility
- Verification of the powders bioactivity and osteogenic properties
- Set up of a production process by P-3DP (Powder-based 3D Printing) for components suitable as bone tissue substitutes

Fabrication of model scaffold suitable for vertebra regeneration

**Transversality of the project**
Materials science and technology, Mechatronics, Bioengineering and Biotechnology

**Ideal candidate** (skills and competencies):
- Four-five year university degree (Master, Laurea magistrale) in Materials Engineering, Chemical Engineering, Biomedical Engineering or similar
- Research experience (final project, tesi di laurea) on glass/ceramic materials or AM technologies.
- Publications coherent with the subject of the proposed project
Topic I

<table>
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<th>Topic: Flexible multifunctional sensors for soft robotics</th>
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<tr>
<td>P.I.: Alessandro Pegoretti, Gian-Franco Dalla Betta (UniTN), Guilherme Barra (UFSC, Brazil)</td>
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<td>Foreign partner institution: Federal University of Santa Catarina (UFSC), Florianopolis (Brazil)</td>
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**Synthetic description of the activity and expected research outcome**

The main aim is the development of flexible pressure and/or temperature sensors for soft robotics and/or actuators based on piezoelectric polymers and relative nanocomposites. In particular, the attention will be focused on poly(vinylidene fluoride) (PVDF) and its blends with conductive polymers [1, 2] and/or nanofillers [3]. Several processing techniques will be explored to enhance the sensitivity to pressure and/or temperature variations including additive manufacturing, electrospinning, solution casting, extrusion and compression moulding.


**Transversality of the project**

The main areas involved in the projects are “Materials Engineering” and “Electronics”. In fact, the polymeric structures will be developed in the Laboratory of Polymers and Composites of DII while part of the characterization of the investigated materials in sensing pressure and/or temperature variations will be performed in the laboratory of Electronics and Microsystems of DII, also in collaboration with FBK.

**Ideal candidate** (skills and competencies):
- A master in Materials Engineering or in Materials Science will be a preferred title. A good knowledge of English is required.
- A specific experience in polymer synthesis, processing and characterization will be also positively evaluated.
**Topic J**

**Topic:** Design and development of an exoskeleton with rehabilitative functions for diseases of the spine

**P.I.:** Vigilio Fontanari, Mariolino De Cecco, Francesco Biral, Matteo Benedetti (UniTN), Werner Schmoelz (Medical University of Innsbruck)

**Foreign partner institution:** Medical University of Innsbruck (Austria)

### Synthetic description of the activity and expected research outcome

The objective of the research is the design and development of an exoskeleton with rehabilitative functions for diseases of the spine. In the design and construction of the exoskeleton, special attention must be paid to its structural functions, to the choice of materials, to the implementation and control of the movements to be imposed, accounting for the most effective loading conditions necessary for the stimulation of the regenerative process at vertebral level in presence of prosthetic interventions; The development of a protocol of use and validation by means of patient tests must therefore be envisaged, based on an efficient instrumentation for the acquisition of information at a cinematic and dynamic level. For this purpose the collaboration with the Medical University of Innsbruck as well as with a rehabilitative department of the local sanitary service (APSS) in the frame of the Ausilia research project will be activated.

### Transversality of the project

The project has a high level of interdisciplinarity, as it requires skills in mechanical design, stress analysis, controls and measurements of kinematic and dynamic variables, metallurgy and material science. Bioengineering and biomedical expertises are also very important to correctly approach the development of the exoskeleton. For this reason, in addition to the indicated tutors, colleagues can be involved and will contribute to different topic of the research: Ilaria Cristofolini, Alberto Molinari, Marco Fontana, Claudio Migliaresi, Antonella Motta.

### Ideal candidate (skills and competencies):

- Master’s degrees in mechanical engineering, mechatronic engineering, materials engineering, biomedical engineering
- Experiences in the use of design tools, in the development of systems for signal acquisition and in signal processing.
- Good knowledge of the English language
- The knowledge of the foundations of biomechanics, bioengineering and biomedical engineering is very important for a correct and profitable approach to the project
**Topic K**

**Topic:** Modeling and simulation of vehicle emissions for the reduction of road traffic pollution

**P.I.:** Daniele Bortoluzzi, Francesco Biral (UniTN), Jens Wahlström (KTH, Sweden)

**Foreign partner institution:** KTH Stockholm (Sweden)

### Synthetic description of the activity and expected research outcome
- Develop a mathematical model of the vehicle dynamics
- Embed the driving action in the model according to different driving styles
- Embed brake, tire and exhaust emission behaviour in the model
- Define a total emission index for the vehicle, study the relevant dynamics and correlations with driving style for the different emissions
- Explore possible emission minimization strategies

### Transversality of the project
The project is based on the integration of the following research areas:

- Vehicle dynamics (Biral, Bertolazzi, Da Lio, Bortoluzzi)
- Laboratory of tribology for brake emission data (Straffelini)
- Emission Analytics Ltd. for exhaust emission data
- KTH Dept. Of machine design, (Ulf Olofsson) for tire emission data

### Ideal candidate (skills and competencies):
- Master’s degree in Mechatronics Engineering, Mechanics Engineering, Automation Engineering
- Fluent English both written and spoken.
- Experience in the modeling and simulation of mechatronic systems.
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<th><strong>Topic</strong></th>
<th>Liquid-based Electro Active Polymers (LEAP) for a new class of soft actuators and generators</th>
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<td><strong>P.I.:</strong></td>
<td>Luca Fambri, Sandra Dirè, Marco Fontana (UniTN), Martin Kaltenbrunner (JKU-Linz, Austria)/ Herbert Shea (Imts -EPFLNeuchatel, Switzerland)</td>
</tr>
<tr>
<td><strong>Foreign partner institution:</strong></td>
<td>Johannes Kepler University, Linz (Austria), EPFL, Soft Transducers Lab, Neuchatel (Switzerland)</td>
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### Synthetic description of the activity and expected research outcome

Recent research works [1-3] have shown that dielectric fluids, with specific properties, can be combined with stretchable or flexible shell structures, made of polymeric dielectric/electrode composite films, to implement a novel type of soft electrically-driven fluidic transducers with self-healing and self-sensing capabilities. This new class of devices can be successfully employed for the realization of actuators, generators and sensors with unprecedented performance and attributes in terms of resilience, adaptability, power-to-weight ratios, functional integration, ease of manufacturing and assembling, extremely low cost of their constituents, superior reliability and lifetime.

The object of research is the development of new type of LEAP actuators and generators based on innovative architectural solutions. The activities will include both experimental developments and theoretical studies.

**Keywords:** HASEL (Hydraulically Amplified Self-healing ELectrostatic actuators), DFT (Dielectric Fluid Transducers), DFG (Dielectric Fluid Generators), EAP (Electroactive Polymers), LEAP (Liquid-based Electroactive Polymers), Soft Robotics, Soft Actuators.

**more info:** Prof. Luca Fambri luca.fambri@unitn.it or Asst.Prof. Marco Fontana marco.fontana-2@unitn.it


### Transversality of the project

Competences on Materials Science, Chemistry and Mechatronics will be relevant in development of the project.

### Ideal candidate (skills and competencies):

You have a recently completed master's degree in Materials Science, Physical Chemistry or Condensed Matter Physics, Bioengineering, or other related fields in
Engineering. You have excellent academic qualifications and a passion for materials research. Strong experimental as well as communicative skills and a pioneering mentality are essential for this project.

- Basics of chemistry, physics and mechanics;
- Knowledge of multiphysics modelling tools is an advantage, but not mandatory;
- English competence: B2 (or equivalent level).